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DATE: June 28, 2001

TO: National Aeronautics and Space Administration

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FROM: Dr. James J. Simpson

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SUBJECT: Final Report for "Validating the Usefulness of Combined Japanese GMS Data for Long-Term Global Change Studies" NASA Grant #NAG5-6135.

PRINCIPAL INVESTIGATOR: Dr. James J. Simpson

PERFORMANCE PERIOD: 10/1/97- 6/30/01

TOTAL BUDGET: \$485,000

The primary objectives of the GMS-5 Pathfinder Project were: 1) to evaluate GMS-5 data for sources of error and develop methods for minimizing any such errors in GMS-5 data; 2) prepare a GMS-5 Pathfinder data set for the GMS-5 Pathfinder Benchmark Period (1 July 95- 30 June 96); and 3) show the usefulness of the improved Pathfinder data set in at least one geophysical application. All objectives were met.

A. ACCOMPLISHMENTS

The following tasks were accomplished during the performance period: Full spatial resolution data and data products are discussed below. GMS Pathfinder is focused on full resolution products.

1. The data exchange procedure for GMS data (GMS-4, GMS-5) between the Australian

Bureau of Meteorology (B o M) and the University of California, San Diego's Digital Image Analysis Laboratory (UCSD/DIAL) was completed. Full resolution, full disc GMS passes were received for three hourly periods for all days during the Benchmark Period. In addition, all daily passes (24 hour day) for a selected two month period were received from the B o M. The approximate size of each GMS full disc (all bands) is about 500 MB. The total volume of raw GMS data for ingest into the GMS Pathfinder processing stream exceeded 2 GB.

2. Stage 1 and Stage 2 processing were designed, implemented, tested and executed on all GMS data received from B o M. Stage 1 processing consists of the following: 1) ingest of GMS data stream in B o M format and conversion to VIFF format for easy use in a UNIX workstation environment; and 2) validation of data (GMT time, file structure, etc...) against inventory files supplied by B o M. Details of the Stage 1 and Stage 2 processing were given in prior progress reports and are not repeated here.
3. Stage 3 processing was completed on all data which satisfied the Stage 1 and Stage 2 data quality/inventory control checks. Approximately 98% of the data passed these tests and were passed on to Stage 3 processing. Stage 3 processing performed the following tasks:
 - a. extraction of visible, water vapor, and infrared (2 channels) data were performed from the GMS-5 disc. The geographical area for the GMS-5 Pathfinder study contains the entire Australian mainland, Tasmania and surrounding seas. The geographical coordinates which bound the area are: (6S, 110E; 48S, 54E; 5S, 154E; 51S, 165E).
 - b. space counts were determined for each scene from the corners of the full disc.
 - c. the entire region was divided into 9 sub-regions, each 1000 x 1200 pixels, for efficient processing on UNIX workstations.
 - d. geolocation was performed on each of the subsections.
 - e. checks for invalid lines, drop-outs, etc..., were performed on each of the subsections.
 - f. coastlines were created for each subsection and matched against coasts in the image data to quantify navigational accuracy.
 - g. a procedure to remap the lower resolution water vapor and IR data to the higher spatial resolution visible data was implemented, tested and validated. Then, it was applied to all IR and water vapor data in the data set.
4. Both GMS-4 and GMS-5 data were examined for sources of noise which could adversely affect the use of the data in both operational weather forecasting and scientific applications. GMS-4/GMS-5 data have stripes and speckled noise. In fact, a new form of x-striped noise, not previously observed in other geostationary satellite data, was detected in the GMS-5

data. This noise appears to be associated with the VISSR -> SVISSR transformations performed by JMA. The noise also is time-varying and strongly suggests that JMA is modifying its VISSR -> SVISSR transformations at random times throughout the GMS Pathfinder Benchmark period. Procedures were developed to reduce the noise in these data while simultaneously minimizing any image distortion introduced into the filtered image. Figure 1 provides an example of the new methods applied to GMS-5 data over a random location in the full disc. A scientific publication resulted from this subtask (Simpson, Stitt and Leath, 1998).

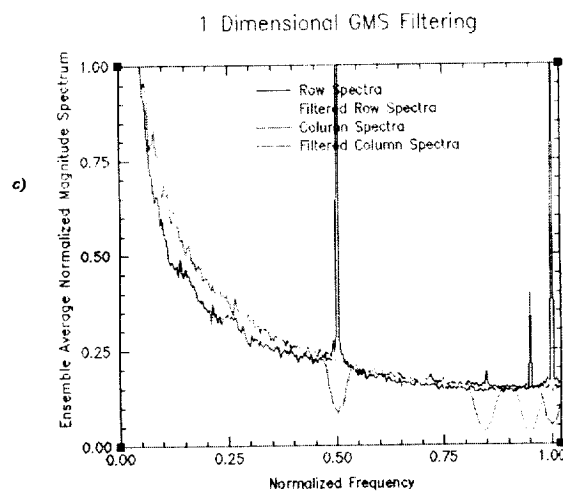
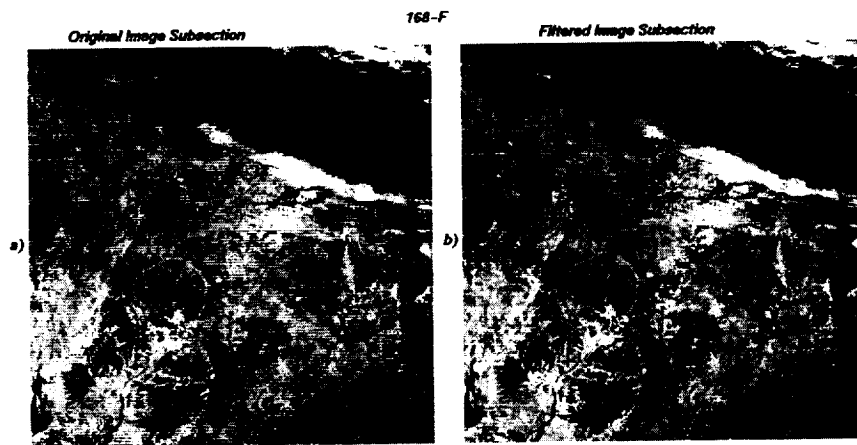


Figure 1: Random GMS-5 visible subsection: a) raw data with stripes; b) destriped data using the new adaptive procedure of Simpson, Stitt, and Leath (1998) and c) spectral results before and after destriping. Both column and row spectra are shown because GMS-5, unlike GOES, has stripes in both dimensions.

5. An overview paper describing the entire GMS-5 Pathfinder project was produced: Simpson, J. J., J. F. LeMarshall, J. Kingwell, A. B. Neal and D. C. Griersmith, (1998), The GMS Pathfinder Project. *Australian Meteorological Magazine*, 47: 225-235.
6. A theoretical basis, using radiative transfer modelling done at Scripps, was combined with an empirical approach done at B o M to provide a calibration/stability check for the visible data taken by the VISSR instrument of GMS-5. The stability of the calibration was evaluated for the entire Pathfinder Benchmark period. A scientific paper resulted from this subtask (LeMarshall *et. al*, 1998).
7. Cloud detection procedures for use with GMS data over both land and ocean, based on our prior GOES Pathfinder work, were developed. An example scene over the GMS-5 Pathfinder Benchmark Region is given in Figure 2. A cloud variability study currently is in progress (Simpson *et. al*, 2001). It will be completed shortly (in cooperation with Dr. John LeMarshall, B o M, Melbourne). Example of validation with *in situ* data at a selected Australian B o M site is shown in Figure 3.

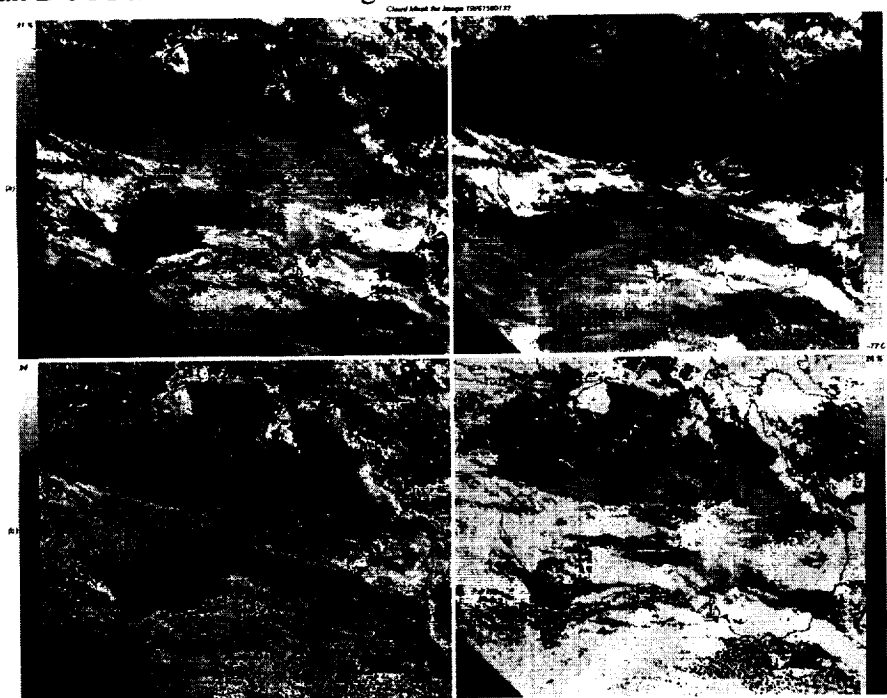


Figure 2: a) GMS-5 scene (visible) over the GMS-5 Benchmark Region; b) thermal data; c) an intermediate spatial statistical variable and d) prototype ocean cloud mask (yellow overlay) and land cloud mask (yellow overlay) based

on prior cloud detection studies done as part of GOES Pathfinder.

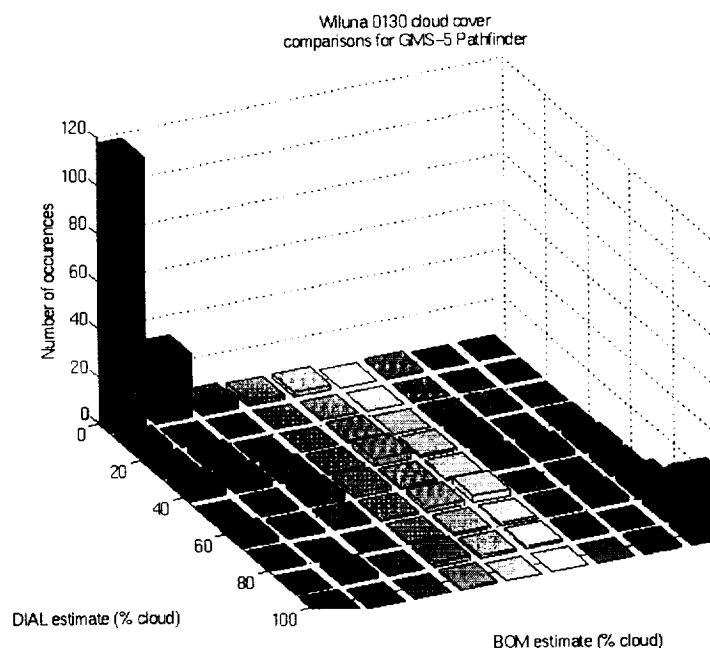


Figure 3: Comparison between GMS-5 derived cloud cover and *in situ* data from the B o M site Wiluna for the entire Pathfinder period. The two agree very well in the limit of completely cloudy or completely clear skies. Agreement also is good for partially cloudy conditions but differences in the two methods of cloud estimation (satellite, *in situ*) make end limits better means of validation (*i.e.*, issues about different length scales resolved by the two measurements are moot).

8. Hardware and software systems were upgraded to handle the GMS-5 Stage 1-Stage 3 processing requirements.
9. The stage four final data set processing software and shell scripts were developed, tested and validated. They were used to produced the **basic Pathfinder Dataset**.
10. Dr. Simpson and two of his staff delivered the **basic Pathfinder GMS-5 dataset** to B o M in November, 2000. Classes were conducted for B o M personnel to: a) familiarize them with the data structure; b) show B o M personnel how to use basic utilities for manipulation of the data set; and c) provide theoretical background on some of the GMS-5 Pathfinder processing steps (see **Appendix for letter from Dr. David Griersmith**, Superintendent Satellite Section, Australian Bureau of Meteorology commenting to Dr. Charlie Kennel, Director of Scripps, on the success of this endeavor).

11. A serious deficiency in the spectral response function of the GMS-5 11 and 12 μm channels was detected (Figure 4). A co-location, near-nadir viewing cross calibration technique, using ATSR-2 as the standard, was developed in cooperation with Drs. C. Merchant and A. Harris of the United Kingdom. A manuscript is near ready for submission (Merchant *et. al*, 2001).

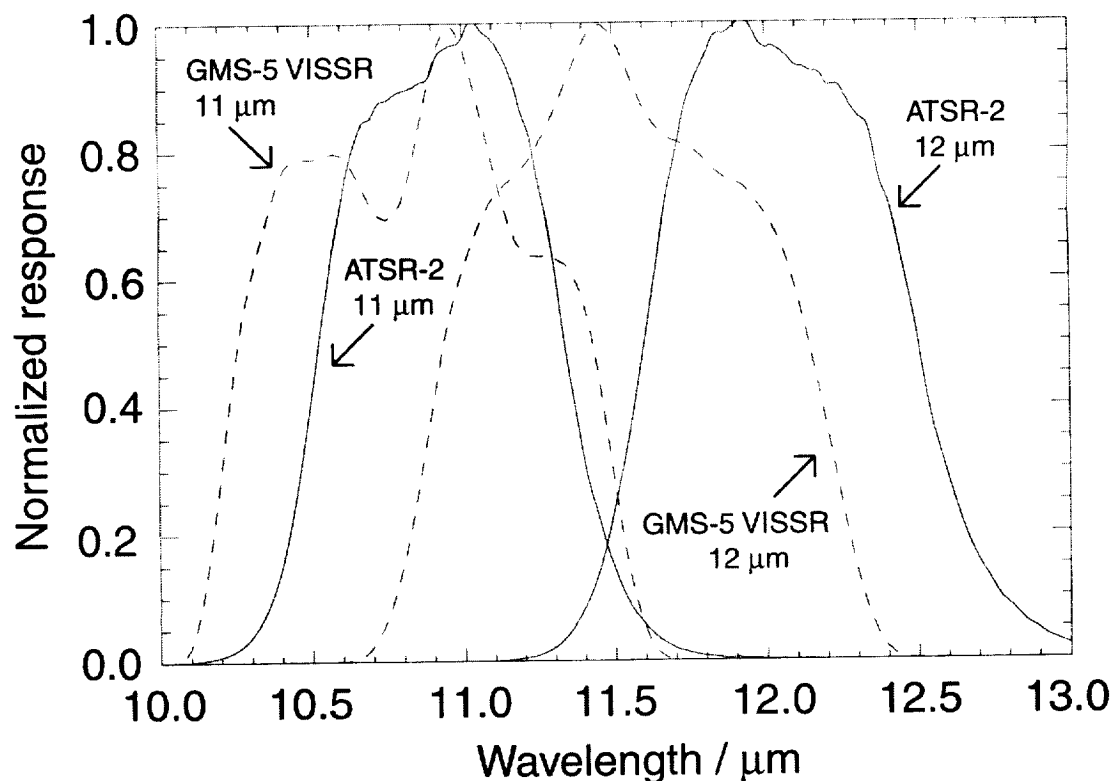


Figure 4: Spectral response functions of GMS-5 and ATSR-2 11 and 12 μm channels. Note overlap in the GMS-5 channels compared to that of ATSR-2 thermal channels. This is a serious source of error in geophysical retrievals using GMS-5 11 and 12 μm data.

12. Application of the new calibration procedure to the tropical Indo Pacific was tested. We have successfully developed a co-located, near-nadir viewing cross-calibration (GMS-5 against ATSR-2), with ATSR-2 taken as the independent standard. Results are quite acceptable. A manuscript (Merchant *et. al*, 2001) is nearly ready for submission. Figure 5 shows a comparison between our result, using the new re-calibrated/corrected and newly derived SST retrieval equation, and a mean Reynold's SST analysis for the same period in 1997. Our new analysis successfully identifies regions of equatorial upwelling observed in independent long-term mean CZCS data for the period (note CZCS data not actually available in 1997) shown below and in SeaWIFS data (for 1998 but not displayed). Upwelling zones do not appear as strong features in the Reynolds analysis. We hope to do a

diurnal SST variability study of the Indo Pacific region with GMS-5 data. More about this later.

1997 Mean SST Comparison May 25 - June 8

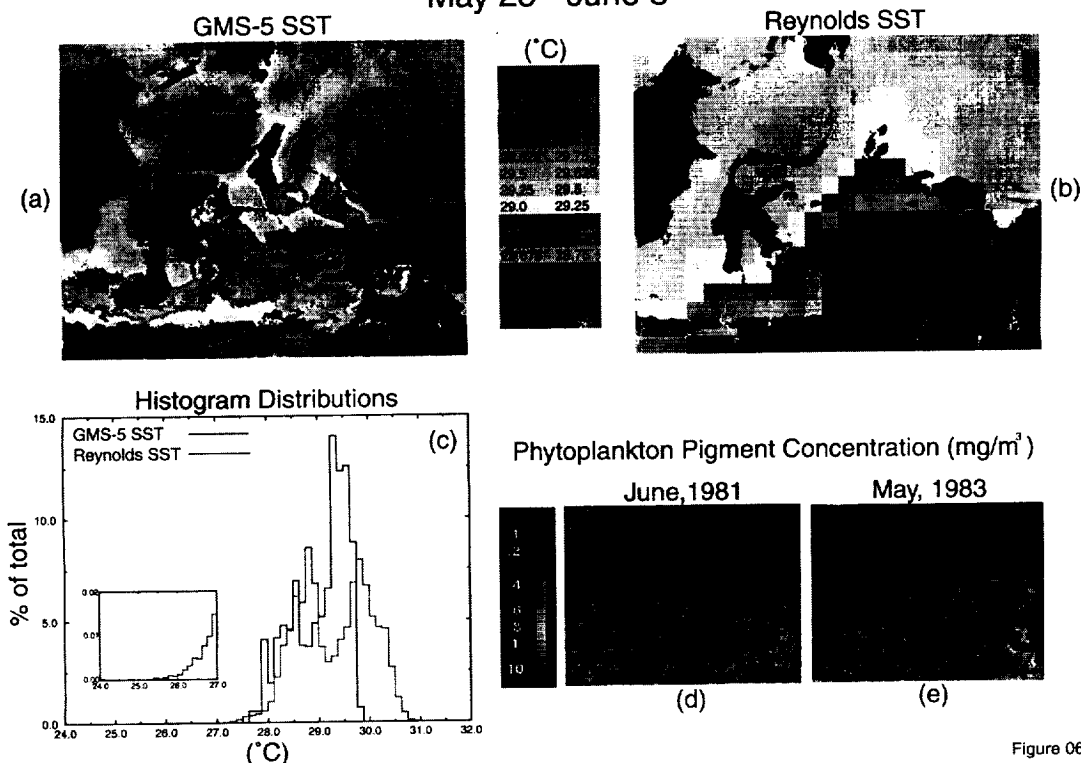


Figure 06

Figure 5: a) GMS-5 analysis for the period cited based on ATSR-2 cross calibration procedure; b) Reynolds SST analysis for the same period; c) Histogram distributions of data in panels a and b. (d, e) Phytoplankton distributions showing upwelling zones from historical CZCS data

B. AUSTRALIAN INTERACTIONS

1. Dr. J. Simpson visited Australia in October, 1997 to: a) attend the 3rd Scientific Working Group meeting; b) attend the GMS Executive Committee meeting; c) develop with B o M and CSIRO personnel the data distribution policy for the GMS-5 Pathfinder dataset; and d) work with Australian scientists on various aspects of the GMS-5 calibration.
2. At the request of the Chinese government, Dr. Simpson visited China in May 1997 (Chinese government paid all travel related expenses) to establish agreements on use and analysis of FY-2 geostationary data. China has expressed interest in the use of some GMS-5 Pathfinder analysis methods for FY-2 data.
3. Dr. Simpson worked with personnel from the Australian Bureau of Meteorology and BMRC while in Australia. Extensive collaboration continuously via phone, fax and email.

4. Dr. Simpson visited Australia in May 1998 to continue all the activities cited under B. 1 above.
5. Dr. J. LeMarshall (B o M/BMRC) visited Scripps for a second time in July/August of 1998.
6. Dr. Simpson and staff delivered the GMS-5 dataset and conducted classes on it for B o M personnel in November, 2000.

C. PUBLICATIONS

1. The GMS Pathfinder Project, 1998: J.J. Simpson, J.F. LeMarshall, J. Kingwell and B. Neal, *Austr. Meteor. Mag.*, 47: 225-235.
2. Improved Finite Impulse Response Filter for Improved Destriping of Geostationary Satellite Data, 1998: J.J. Simpson, J.R. Stitt, and D. Leath, *Remote Sens. Environ.*, 66, 235-249.
3. Satellite Calibration Using a Collocated Nadir Observation Technique: Theoretical Basis and Application to the GMS-5 Pathfinder Benchmark Period, 1999: J.F. LeMarshall, J.J. Simpson and Z. Jin, *IEEE Trans. Geosci. and Remote Sens.*, 37: 499-507.
4. Cloud Variability over Australia during the GMS-5 Pathfinder Study Period. J.J. Simpson, J.F. LeMarshall and A. Schmidt, work in progress.
5. A Cross-Calibration of GMS-5 Thermal Channels Against ATSR-2, 2001: C.J. Merchant, J.J. Simpson, A.R. Harris. In final internal review prior to submission.

APPENDIX

COPY



Bureau of Meteorology

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Dr Charles F. Kennel
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Dear Dr Kennel

I am writing to you in relation to a recent visit to the Bureau of Meteorology by Dr James Simpson and two of his staff concerning the international GMS Pathfinder Project. I am the Bureau's national manager for satellite activities and my area was host for the visit. We have been involved in the Pathfinder Project for many years now and have been thrilled to see the Project unfold and produce many valuable publications and insights into GMS data and its use.

During the visit, Dr Simpson and his team assisted the Bureau of Meteorology via tasks including the following:

- provision of the extensive GMS Pathfinder data set and detailed descriptions to enable efficient data handling and access;
- provision of software tools to access the data including quality controls;
- provision of important information concerning the GMS calibration, its accuracy and improvement - this is very important in use of GMS data and generation of further products like SSTs, volcanic ash and so on.

You may be aware that GMS data is the most important type of satellite data used by the Bureau of Meteorology in its services, research and climate studies. The Bureau is therefore hoping that in time it will be able to build on the results of the GMS Pathfinder Project by generating further high quality datasets like the GMS Pathfinder dataset, and implementing new systems to generate data of greater accuracy and operational and research utility. Also the Japan Meteorological Agency with whom the Bureau has extremely close ties under the umbrella of a Treaty level agreement, has been closely monitoring progress with the Project because of its impact on potential major improvements to Japan's use of GMS data and at a broader level, its geostationary meteorological satellite program.

Dr Simpson and his team have helped us greatly with the Pathfinder dataset/Project and on behalf of the Satellite Section and the Bureau I would like to thank you and your Institution for your support and most valuable collaboration. Dr Simpson's visit has been part of an ongoing project of major importance to the Bureau's satellite activities and it has been a pleasure to act as host to him and his team. His outstanding world-class research excellence and the very high skills of his staff do great credit to your Institution.

Once again thank you to you and your staff, especially Dr Simpson and his team.

Yours sincerely

(Dr) David Grier-Smith
Superintendent, Satellites

7 December 2000

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